

Transport in Quantum Wires

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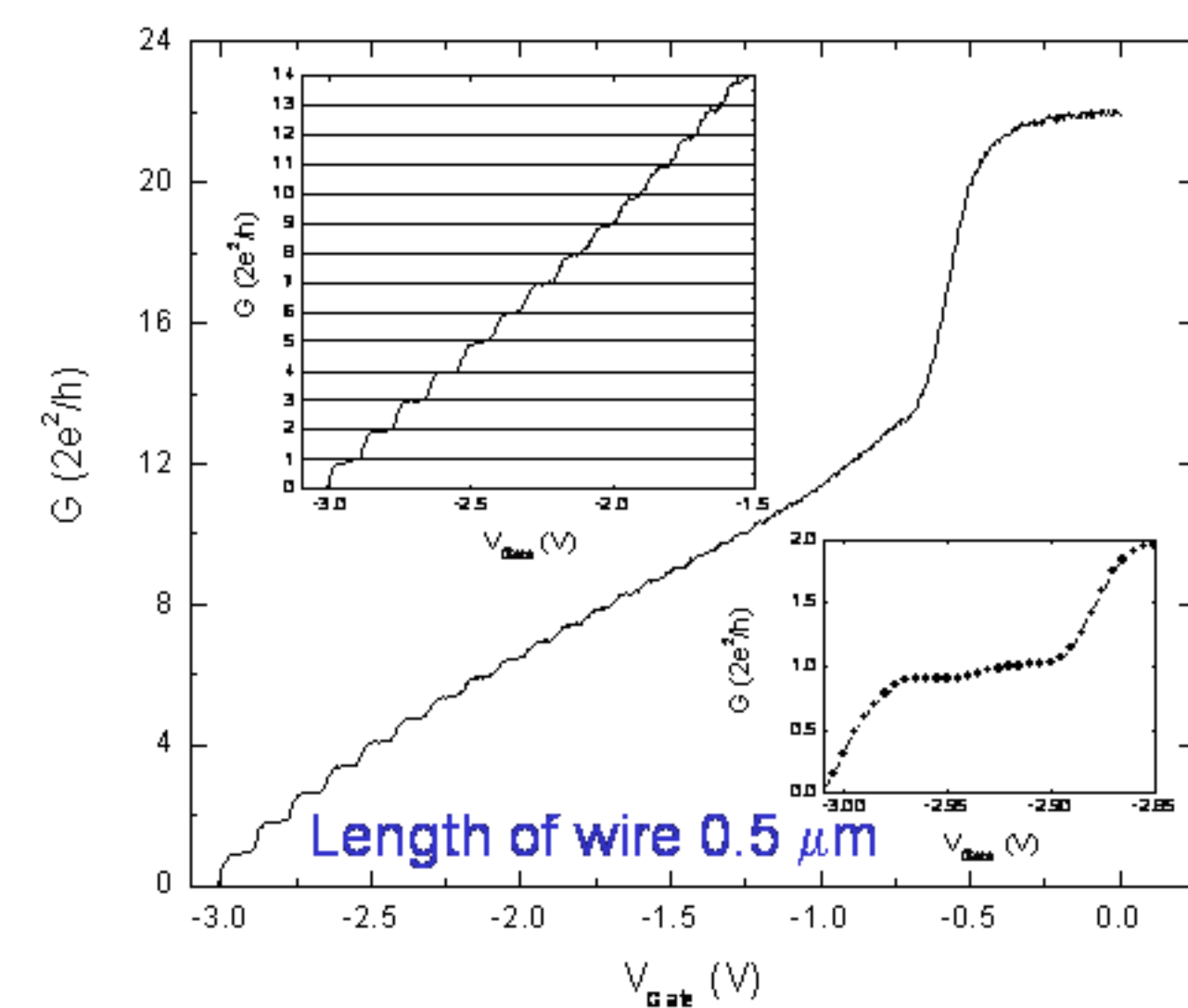
Motivation

- Single wires represent a low-dimensional quantum system where energy scales and the wavefunction can be manipulated
- Potential for high frequency device applications
- Coulomb interactions in 1D systems lead to interesting many-body interactions, such as Luttinger liquids
- Our goal is to study interacting nanostructures
- The double quantum wire system provides an excellent experimental realization of coupled nanostructures

Molecular-Beam Epitaxy Growth of 2D Electron Systems

- Sandia produces high quality single and double layer 2D electron systems in GaAs/AlGaAs heterostructures
- These GaAs/AlGaAs semiconductor crystals have measured 2D electron system mobilities in excess of $\sim 10^7$ cm²/Vs, which corresponds to a mean free path on the order of 100 μ m

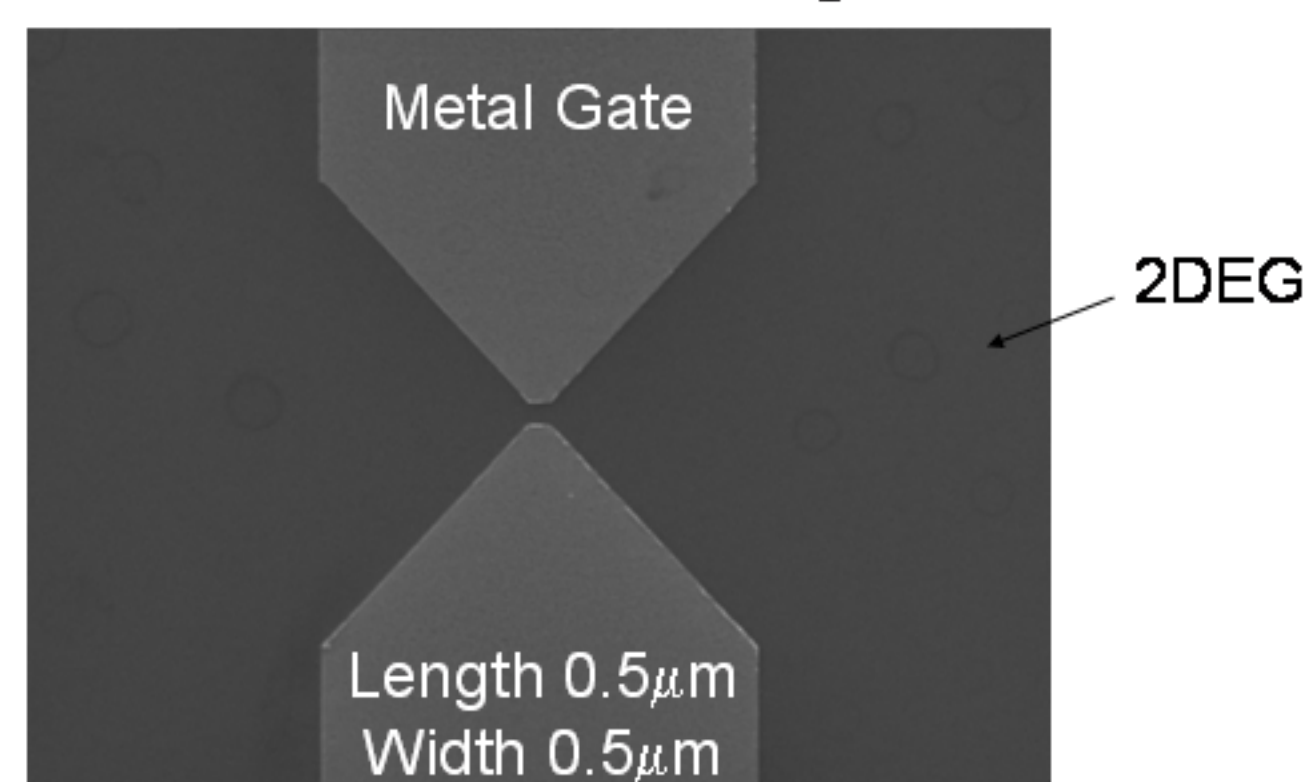
Single Quantum Wires



- Quantum wires defined by split-gates via electron-beam lithography
- Allows experimental control of the wire length

- Length of wire 0.5 μ m
- 14 conductance steps @ T = 0.3K
- 2-probe with series correction of 550 Ω

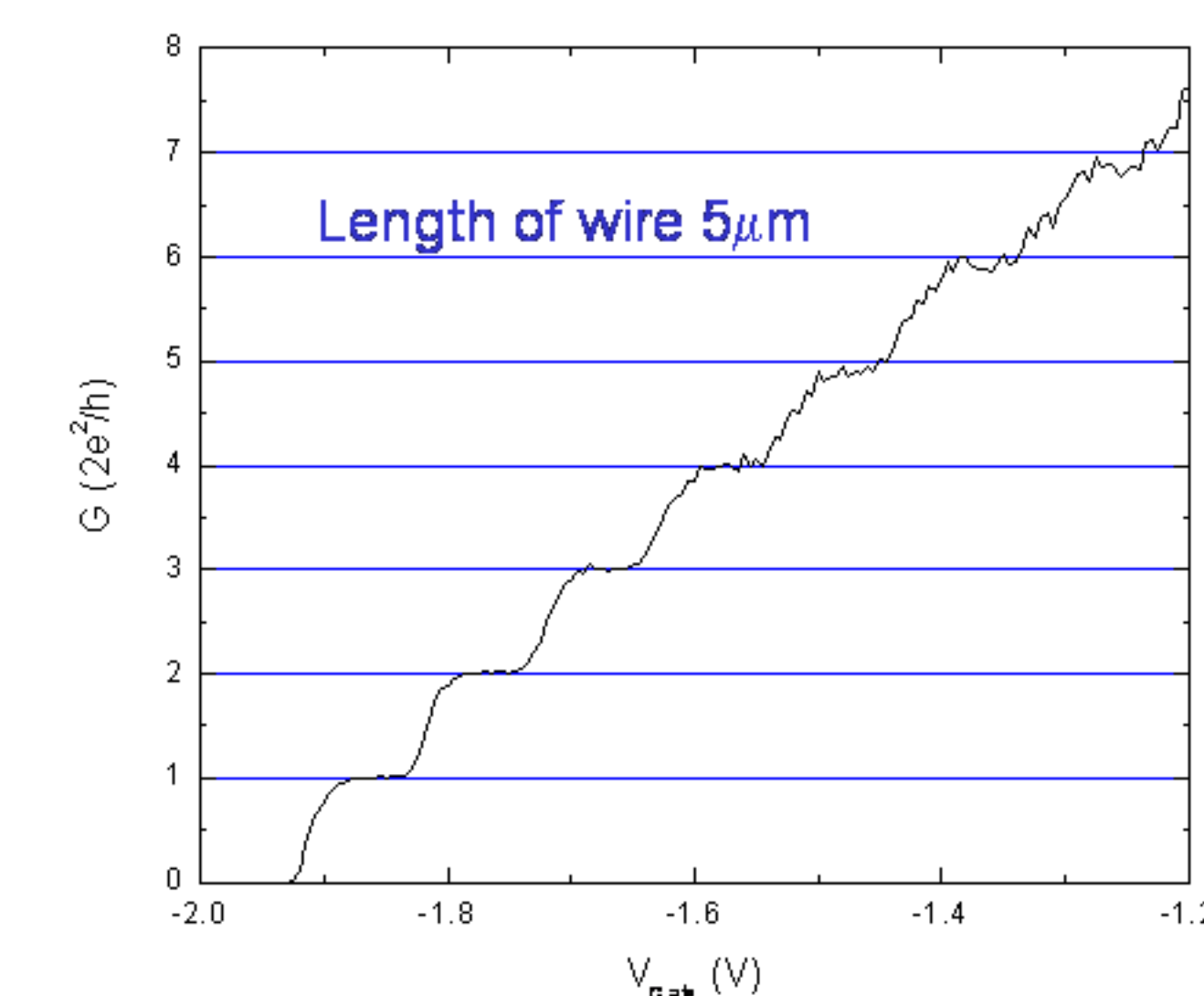
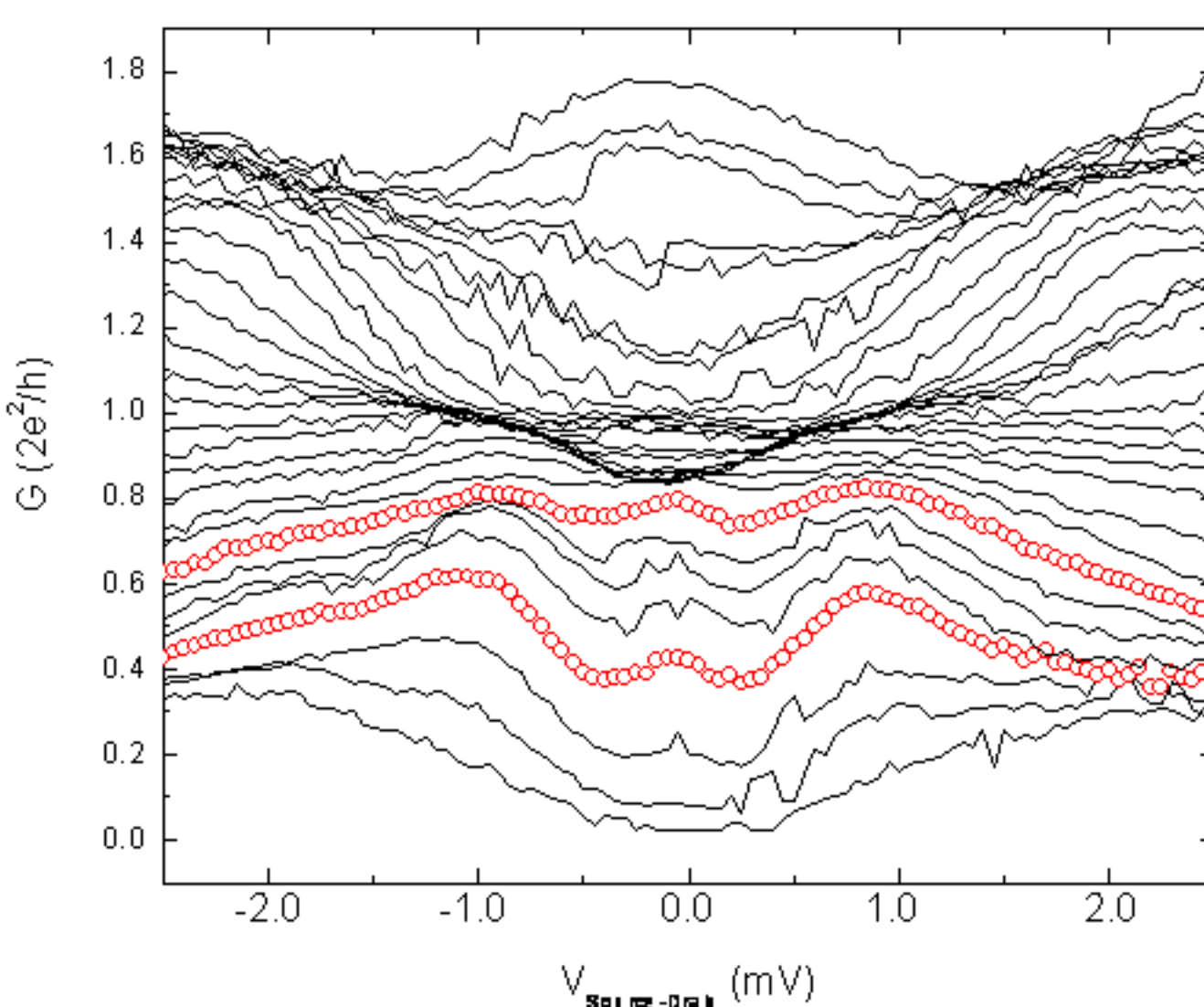
Quantum wire 0.5 μ m in length



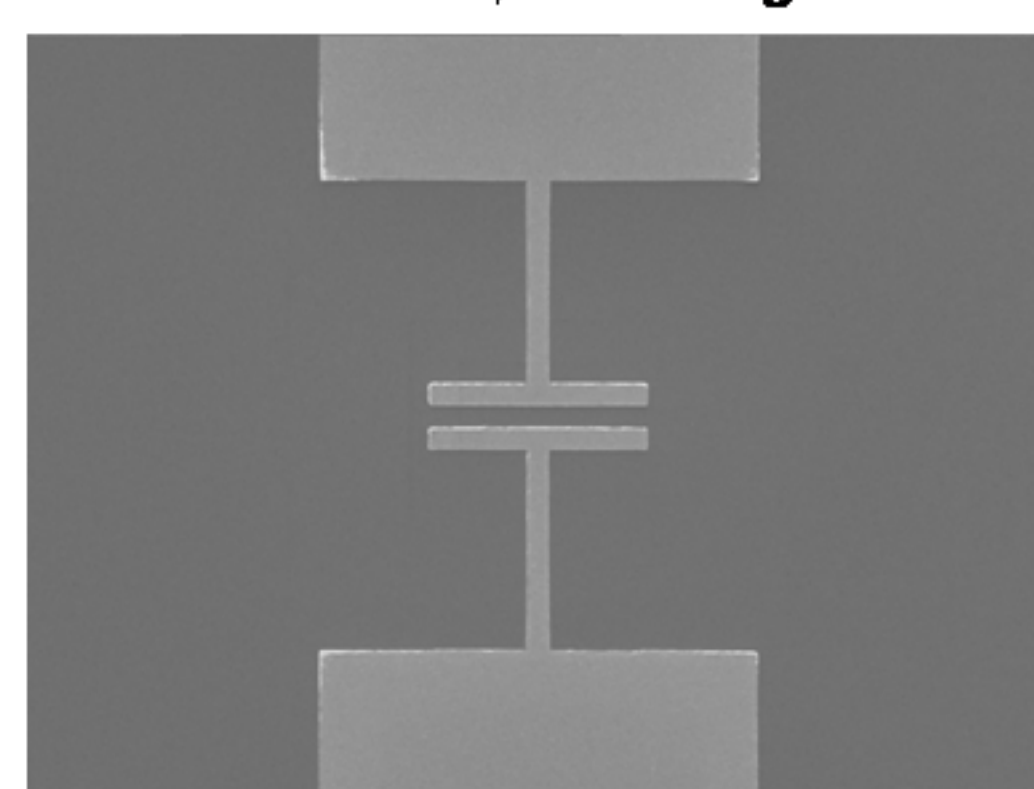
- Evidence in the literature suggests the structure below the lowest 1D subband is due to the Kondo effect
- IV curves bring out additional structure in transport measurements
- We observe the expected accumulations at 1.5, 2.0, etc..., while observing an unusual splitting of the first conductance plateau

Ballistic to Diffuse Crossover

- Study of ballistic transport in bilayers requires long wires
- The use of high quality 2D electron systems grown at Sandia enables the observation of ballistic transport in one of the longest split-gate quantum wires to date

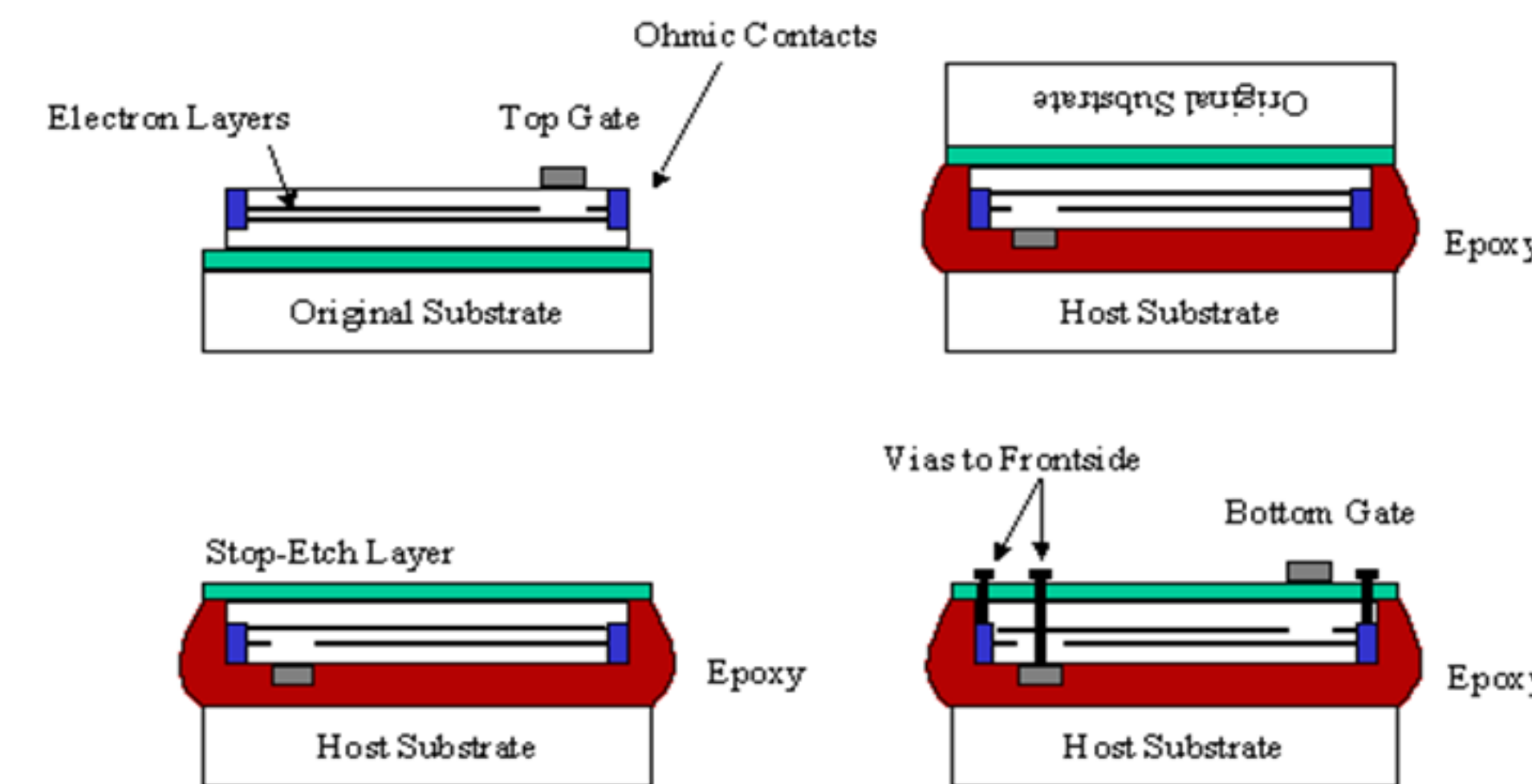


Quantum wire 5 μ m in length



EBASE (Epoxy-Bond-And-Stop-Etch)

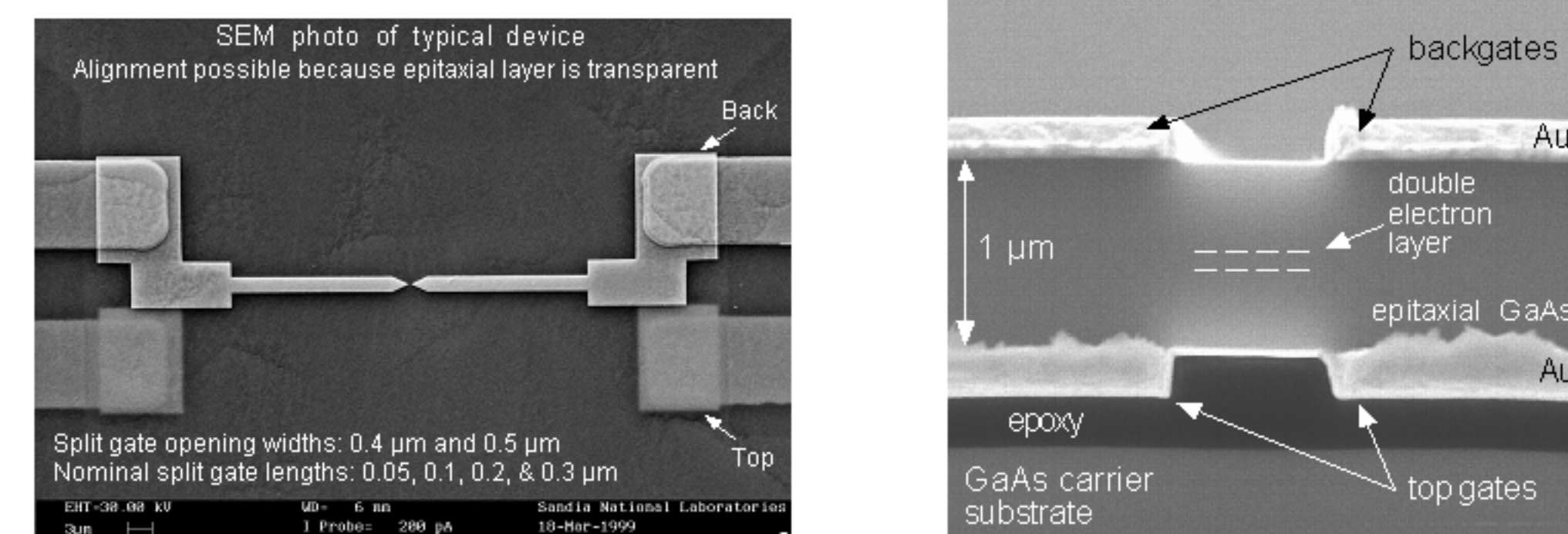
- Novel technique developed at Sandia that allows dual side processing



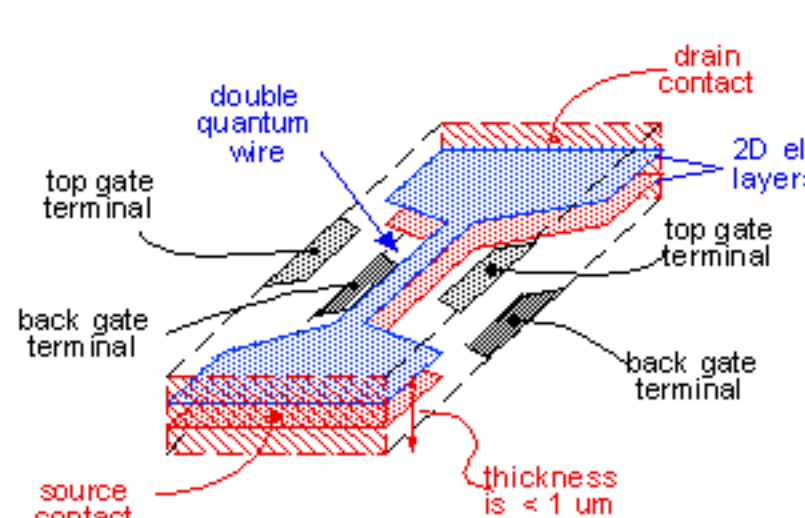
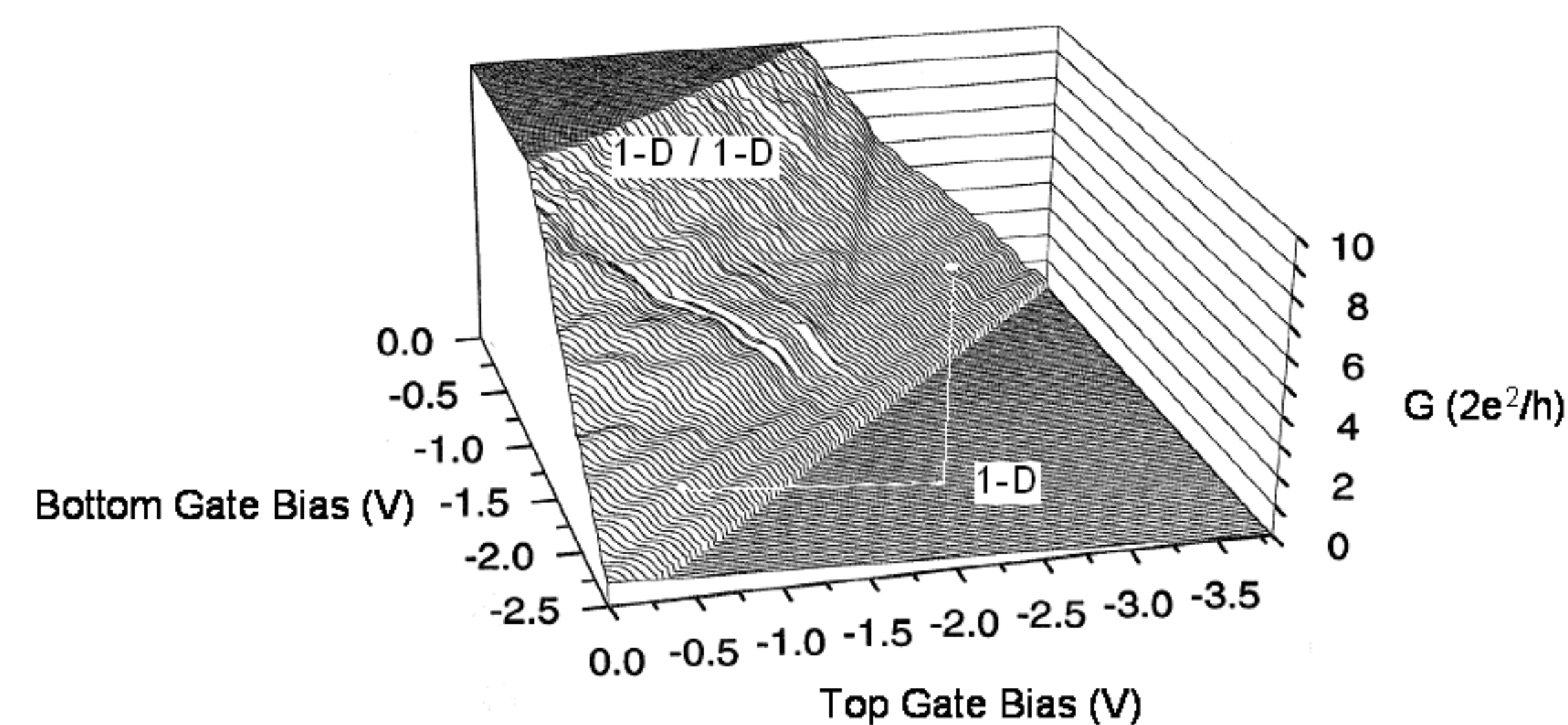
- Through the use EBASE, via electron-beam lithography, top and bottom depletion gates can be placed as close as 200nm from the 2D electron gas.

Double Quantum Wires

- Numerous experiments are in progress with double quantum wire and double quantum dot systems



- Waterfall plot shows that the two quantum wires are independently tunable



- Uniform conductance steps in regions labeled 1D
- Complex interference of the steps when both 1D wires are occupied

Technique allows new experiments and devices

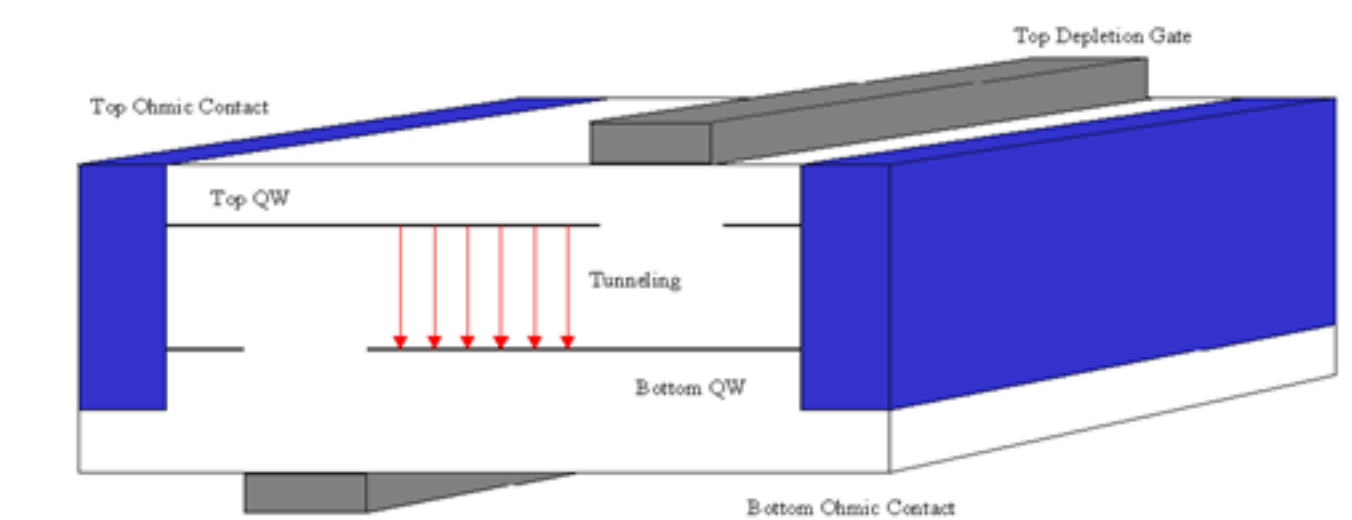
- Coupled lower-dimensional structures
- 2D, 1D, and 0D, and any combinations
- Vertical tunnel coupling ideal for control
- Independent contacting of structures

M. A. Blount *et al.*, Physica E, **6**, 689 (2000)

Future Directions

Independently Contacted Double Quantum Wires

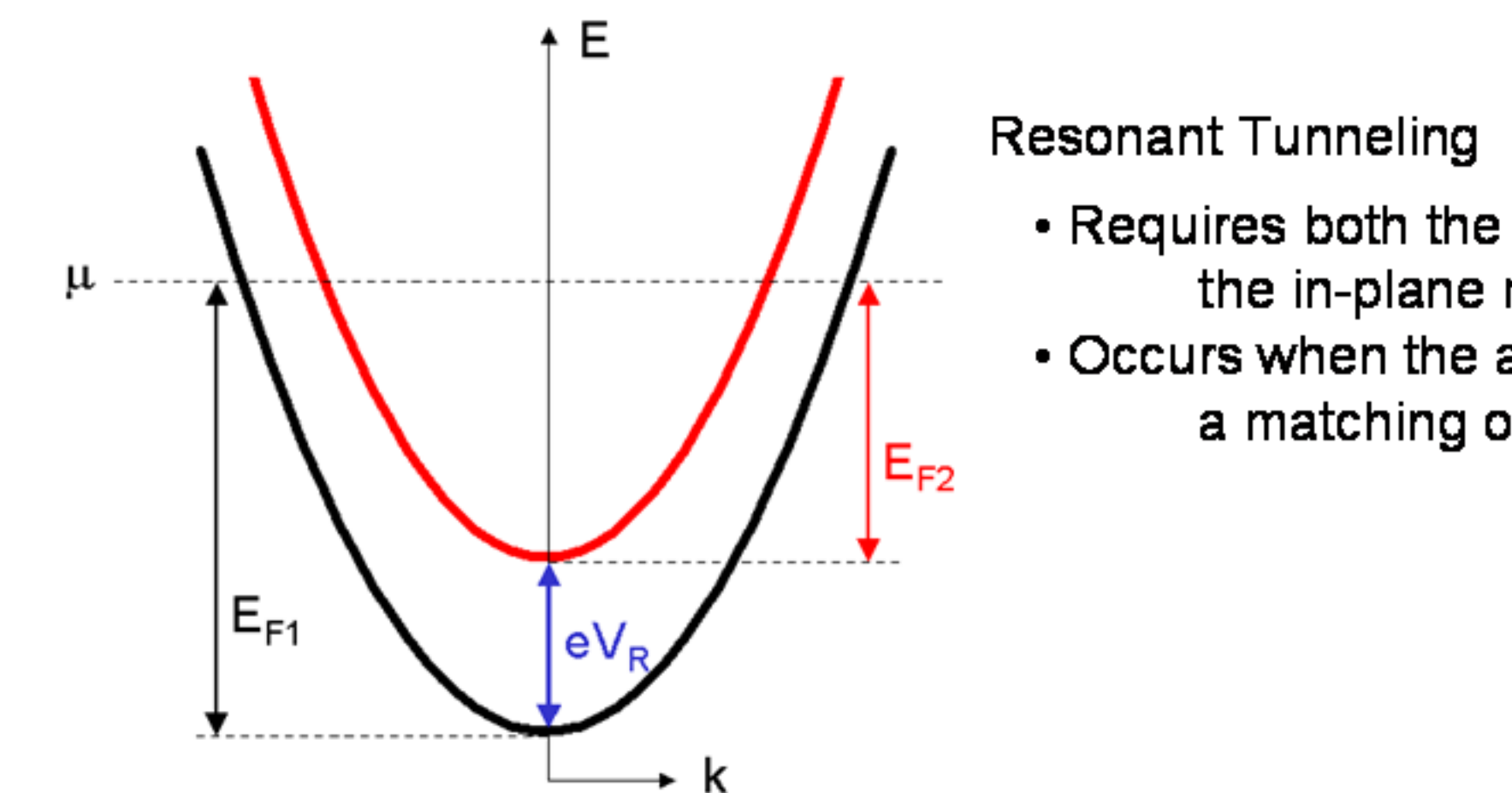
- Independent transport measurements in each layer and tunneling between layers. This opens up new experiments: Tunneling between layers, Coulomb drag between layers



Tunneling between Layers

- Using EBASE, electron-beam lithography, and high quality heterostructures, available at Sandia, we can study the following systems:

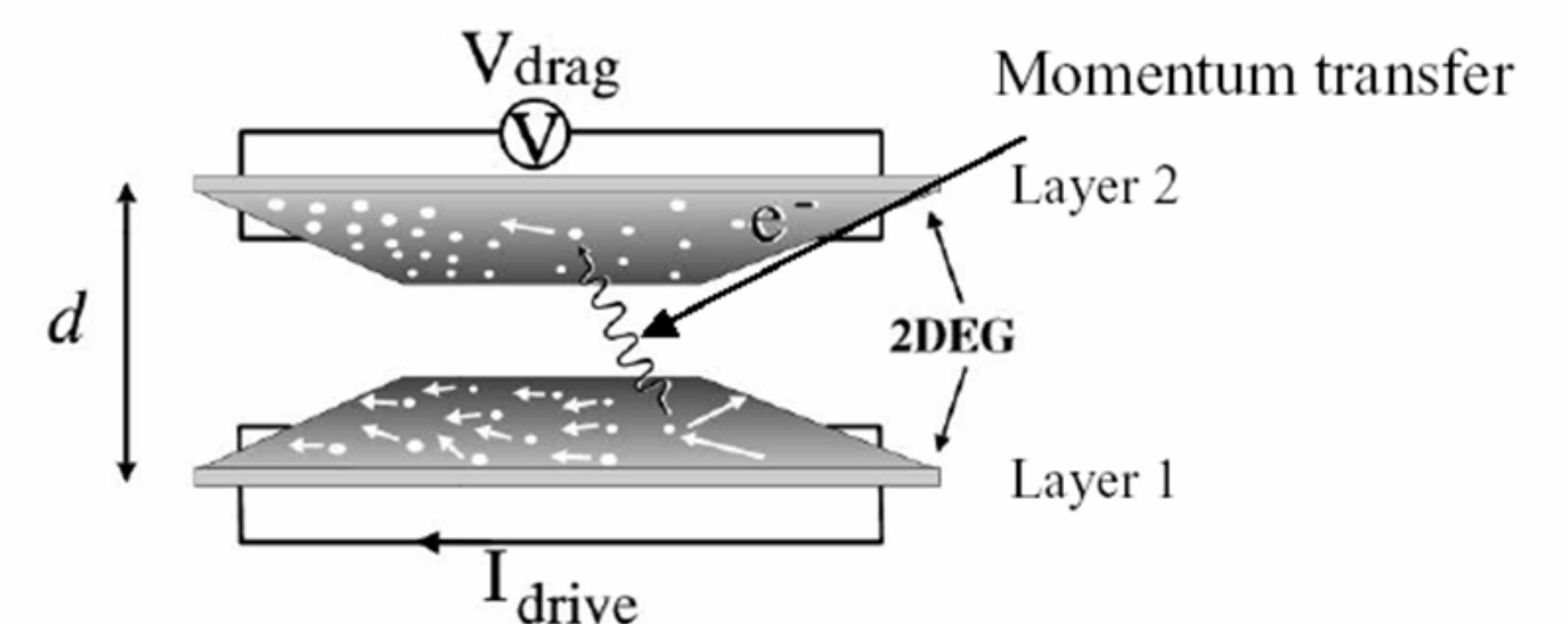
2D-2D
2D-1D
1D-1D



Resonant Tunneling

- Requires both the conservation of energy and the in-plane momentum
- Occurs when the applied voltage, V_R , leads to a matching of energy and momentum

Coulomb Drag between Layers



Drive Current in Layer 1
Drag Voltage in Layer 2
Momentum Transfer by e-e interaction

Figure from "Coulomb Drag between Ballistic Quantum Wires" Nano Transport Laboratory Self-Seminar by S. H. Lee

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